

LIDAR

What is LIDAR?

LIDAR is the acronym for Light Detection and Ranging. Laser light acts as the carrier wave for lidar in a manner similar to the way that radio frequency waves act as the carrier wave for radar. Lidar currently has three main uses in remote sensing. As a range-finder it has been widely used in surveying, weapons systems, navigation and even in high profile applications such as the America's Cup races and Space Shuttle docking maneuvers. The other two uses of lidar are only now emerging from years of research into real world applications. This research has yielded Doppler lidar systems to remotely analyze atmospheric Doppler shift for wind measurement and DIAL (Differential Absorption Lidar) which can be used for detecting specific particulates in the atmosphere. Their use in these fields has been supported by other recently evolving technologies that support the useful application of lidar. Precision inertial and GPS navigation technologies and significant portable computational power are now widely available allowing measurement of atmospheric conditions and topographic data from moving platforms that would not have otherwise been feasible. These technological advances provide lidar applications with real time sensing advantages over more traditional remote sensing methods. (NASA, sparcle)

Lidar Mapping

Lidar range-finders are the closest analogue to traditional radar. The use of laser echo ranging in place of radar allows more precise range and spot location determination than radar. Among the many applications of laser range-finding, lidar has been integrated with aerial photographic mapping techniques to rapidly process terrain data. One of these systems is used by Woolpert LLP to produce aerial surveys. The combination of GPS, precision inertial measurement systems and the co-processing of photogrammetric data with lidar data has allowed them to accelerate processing by 30%. Lidar itself has less demanding meteorological requirements than photogrammetry, only requiring clear air between the sensor and the ground and no sun angle requirements. For survey areas where ground access is not possible, lidar provides more reliable data than photogrammetry alone would have otherwise provided. (Brinkman and O'Neill)

Besides the current military uses of laser-range finding, lidar terrain data could supplement existing elevation data. Precision weapons targeting requirements may drive terrain measurement requirements to smaller tolerances than are readily available. In areas where strike operations are imminent, lidar data derived from an overhead sensor or reconnaissance platform could augment incomplete terrain databases.

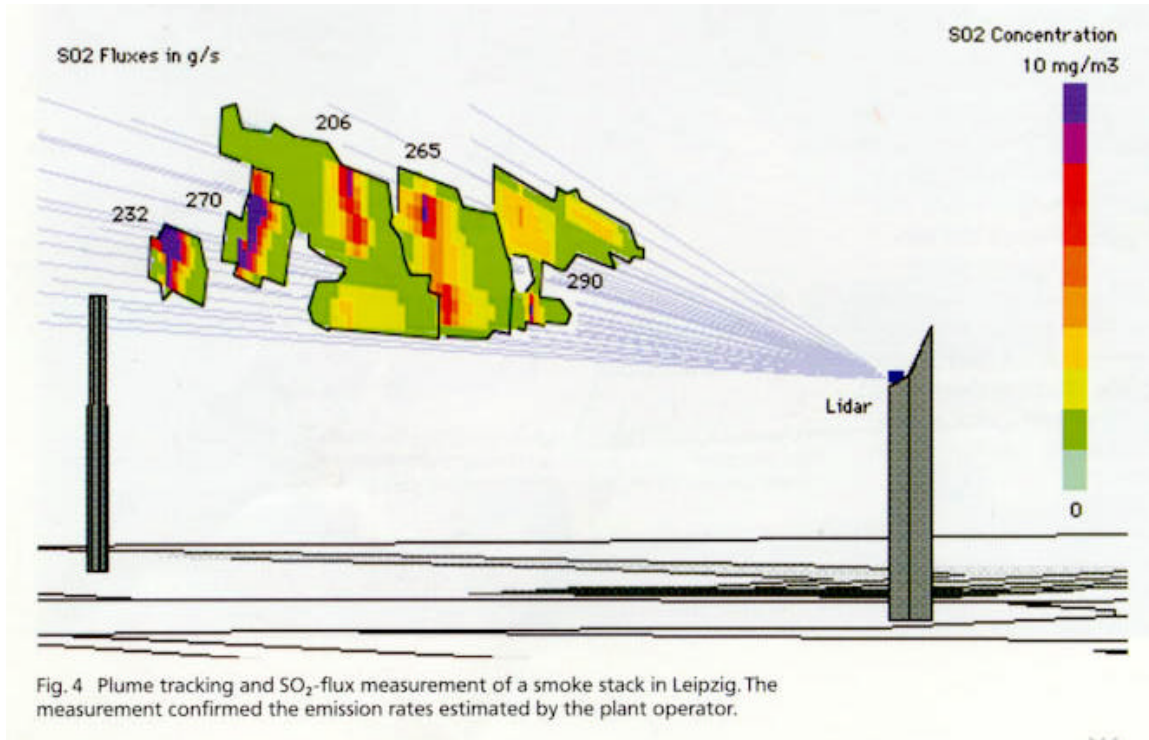


Figure 1. (ELIGHT Laser Systems GmbH, Berlin Germany)

DIAL

Differential Absorption Lidar is a more complex use of lidar than range-finding. It uses two beams of laser energy, of similar but subtly different wavelengths to produce a three dimensional measurement of particulate concentration in the atmosphere. The two wavelengths are chosen so that only one of them is absorbed by the target particulates, but they are close enough in wavelength that they otherwise have similar propagation properties. The absorption of only one of the two wavelengths highlights the presence of the target particulate. Figure 1 is an example of its use in pollution measurement at a smokestack. (Preville)

DIAL has significant potential for military use including counter-stealth and ballistic missile tracking. While lidar alone is insufficient to solve either of these

problems, it may enhance the effectiveness of other sensors. The concept of sensor fusion is the merging of all computer enhanced data into one tactical display similar to the concept of multispectral imaging in remote sensing. Lidar could enhance counter-stealth or ballistic missile tracking efforts with its ability to three dimensionally locate particulates in the atmosphere. Similar to how ship wakes are obvious patterns in the sea, contrails are obvious patterns in the atmosphere that betray the presence of combustion engines. Contrails are the visible legacy of these engines; while aircraft altitudes are varied to eliminate the visible contrail, the products of combustion still exist in the atmosphere even when they are not visible. Lidar could be tuned to these exhaust product absorption wavelengths and be used to detect the contrail's anomalous pattern of these particulates in the atmosphere. Once the stealth aircraft or ballistic missile was localized with lidar detection of the contrail, other sensors could then concentrate upon a smaller sector making effective tracking more likely.

Doppler LIDAR

MACAWS (Multi-Center Airborne Coherent Atmospheric Wind Sensor) is a NASA/NOAA/JPL program to measure atmospheric movement remotely. It is an aircraft hosted testbed to develop technology and methodology for a space-based platform. In a manner similar to Doppler radar, Doppler lidar uses the measurement of small particle velocities to represent movement of the atmosphere. Doppler lidar is not seen as a stand-alone technology, but one that has specific advantages that can augment current techniques. It has several strengths over Doppler radar in that it has less beam divergence, is unaffected by proximity of complex terrain and cloud formations and does not suffer from reflective distortion; however, it cannot penetrate thick clouds or rain. Doppler lidar has been used in several wake turbulence studies, demonstrating its effectiveness in providing precise three dimensional velocity measurement. (NASA MACAWS; AW&ST, May 15 and July 31, 2000)

Figure 2. MACAWS system specifications (NASA MACAWS):

CHARACTERISTIC	NOMINAL	RANGE
Wavelength (μm)	10.6	9 - 11
Transmitter	CO ₂ gas TEA laser	
Energy per pulse (J, long-pulse mode)	0.8	0.6 - 1.0
Beamwidth to e ⁻² power points	20 cm	
Pulse duration (μs)	3	0.4, 3 ^a
Laser linewidth (kHz)	~300	
Pulse repetition frequency PRF (s ⁻¹)	20	0.1 - 30
Telescope diameter (m)	0.3	
Line-of-sight resolution (m)	300	150 - 1200
Number of scan planes	5	1 - 5
Vertical resolution (km) ^b		0 - 12.5
Wind velocity accuracy (m s ⁻¹)	~1	
Nyquist radial velocity (m s ⁻¹) ^c		75
Coverage (km) ^d		10 - 30
DC-8 endurance (hr) ^e	8	
DC-8 cruising altitude (km)		0.3 - 12.5

^a Duration in which 80 percent of pulse energy is emitted
^b Dependent on range and angular separation between scan planes
^c Actual ground-relative velocity limits may differ depending on relationship between line-of-sight components of airspeed and ground velocity
^d Dependent on distribution of aerosol backscatter and extinction
^e Missions beyond 8 hr duration are possible with crew augmentation

Doppler lidar has widespread applicability. Weather prediction to a carrier battlegroup or single unit in the open ocean always benefits from more accurate weather data to input in forecasting models. Directly measured meteorological data is not usually available for strike operations. The ability to provide accurate winds aloft data provides more accuracy to the weapons system employed. If this data is available preflight, more effective flight paths can be planned. If the information is available real-time on an aircraft, the ballistics of weapons release could more accurately reflect winds the weapon would pass through on its way to the target, improving even a precision guided weapon's effectiveness by optimizing its trajectory. Lidar's small spot size would complement stealthy aircraft with its low probability of intercept.

Lidar has demonstrated its effectiveness in laser range-finding applications. Whether it expands its military use into lidar remote mapping, it has significant potential in the Doppler and DIAL roles. Remote weather determination through Doppler has worldwide applicability for military forces. Lidar's potentially most significant new purely military applications would seem to be in stealth and ballistic missile counter-efforts, yet DIAL will require significant expenditure before it can yield significant

benefits. Lidar is not a stand alone technology, but in concert with other sensors can provide additional insight. Its requirement for clear air to be effective limits its military utility, but does not preclude it. It has capabilities for remote precision measurement that otherwise would not be available.

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